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Forestry Research West

A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

Forestry Research West

In This Issue

Cover

The western spruce budworm is the most widely distributed and destructive forest defoliator in western North America. Scientists at the Rocky Mountain Station are working to develop a better understanding of impacts caused by this insect and other pests in our nation's forests. Details begin on page 1

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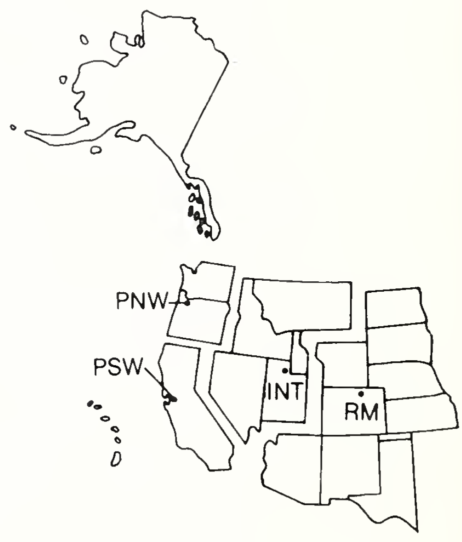
Western Forest Experiment Stations

Pacific Northwest Research Station (PNW)
P.O. Box 3890
Portland, Oregon 97208

Pacific Southwest Forest and Range Experiment Station (PSW)
1960 Addison St.
Berkeley, California 94704

Intermountain Research Station (INT)
324 25th Street
Ogden, Utah 84401

Rocky Mountain Forest and Range Experiment Station (RM)
240 West Prospect Street
Fort Collins, Colorado 80526-2098



245

On the heels of the western spruce budworm

by Rick Fletcher
Rocky Mountain Station

"The first recorded outbreak occurred in 1909 on Vancouver Island in British Columbia. Since that year it has steadily spread into the forests of western Canada, and throughout much of the western U.S. If you're experiencing some of the same frustrations I am, you're aware of the lack of usable information for combating this pest." A group of resource specialists, who met recently at a workshop in Estes Park, Colorado, was discussing the western spruce budworm (*Choristoneura occidentalis* Freeman). This insect is the most widely distributed and destructive forest defoliator in western North America. It is found in the Rocky Mountains, from Arizona and New Mexico to southeastern British Columbia, west to Vancouver Island, and south into Washington and Oregon.

The feeding intensity of budworm larva, such as this on a white fir, is greatest in late spring.

Due to increasing concern over forest pests, the USDA Forest Service is involved in a coordinated effort, involving the Pacific Southwest, Southeastern, and Rocky Mountain Stations, to develop a better understanding of impacts caused by the budworm and other pests in our nation's forests.

Specialists meet

The Estes Park workshop was designed to help develop a set of information and research needs concerning the impacts of the budworm on important forest resource values in Colorado, New Mexico, Arizona, and parts of Utah. Attendees included USDA Forest Service personnel from NFS, Research, and Forest Pest Management, along with several university representatives—all with a broad range of experiences, concerns, and ideas.

Research Plant Pathologist Terry Shaw, who organized the workshop and heads the Rocky Mountain Station project "Pest Impact Assessment Technology", set the tone for the meeting by outling three major concerns: "First, our understanding of the effects of the budworm on forest resources is, and probably always will be, imperfect. Therefore, research should be directed toward the testing of hypotheses about how and to what extent budworm effects are manifested. Second," he said, "studies have been conducted on the problem before. It is therefore important to ensure that previous research is not repeated, and that we try to capitalize and improve on the best current understanding of budworm effects on forest resources.

Finally, there are many perspectives on what the important issues and concerns are. Management needs for budworm research are different for different persons and groups. Without a clear definition of what the problem is, studies are likely to be unfocused and ambiguous. Therefore, the problems and concerns of budworm effects must be clearly defined at the outset of any research. That's why we're here today!"

Workshop results

The 2½ day workshop consisted of a structured set of exercises that drew on the expertise, knowledge, and concerns of all participants. These exercises helped identify: (1) the important issues related to budworm effects on forest resources in the Southwest; (2) the resource values that are attributes or components of the environment for which there is concern; and (3) the temporal horizon and spatial extent over which budworm affects these resource values; all of which led to (4) development of a conceptual model of budworm effects on forest resource values.

This model (Figure 1) provided a framework for describing how budworm defoliation affects resource values through a series of connections from host condition, to environment, to characteristics of the budworm. Once the important links between budworm and specific resources were identified, it was possible to discuss how much information is available and the necessity of additional research. These discussions generated a "preliminary" set of essential research priorities:

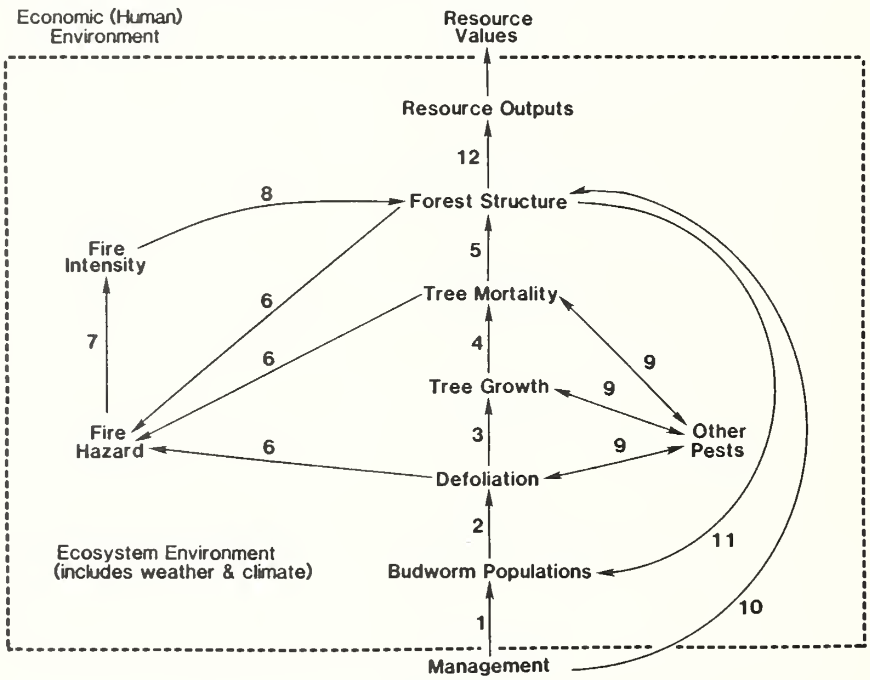


Figure 1

Link 1: Direct control of budworm populations

Link 2: Effect of budworm on host tree and stand defoliation

Link 3: Effect of budworm defoliation on host tree growth

Link 4: Effect of changes in tree growth caused by budworm on tree mortality

Link 5: Effect of budworm-induced host tree mortality on forest structure

Link 6: Effect of budworm defoliation and budworm-induced changes in tree mortality and forest structure on fire hazard.

Link 7: Effect of changes in fire hazard on fire intensity

Link 8: Effect of changes in fire intensity on forest structure

Link 9: Interaction of the budworm with other pests

Link 10: Management influences on forest structure

Link 11: Effect of forest structure on budworm populations

Link 12: Effect of changes in forest structure, directly or indirectly caused by budworm, on resource values

Linkage description of conceptual model.

EFFECTS OF BUDWORM DEFOLIATION ON HOST TREE GROWTH AND MORTALITY, AND THEIR SUBSEQUENT EFFECTS ON FOREST STRUCTURE. Much of the knowledge on budworm populations and their effects on tree and stand development and mortality is reflected in models that were developed by the CANUSA project (see "Scientists Attack the Western Spruce Budworm Problem": Forestry Research West, March 1983, pages 4-8). These models include the combined Prognosis-Budworm program and various risk rating systems. Although data for these models were collected from a wide variety of stands, relationships for budworm sampling, populations, and impact and risk models need to be further developed and tested to produce a localized version suitable for use in the Southwest.

An important area that specialists felt needed more research centers on the INTERACTIONS OF THE BUDWORM WITH OTHER FOREST PESTS. The common pests that might interact with budworm in the Southwest are dwarf mistletoe, root diseases, Douglas-fir and mountain pine beetles, and Douglas-fir tussock moth. The major kinds of interactions between these pests and budworm were identified as predisposition of trees by budworm to root rot, Douglas-fir beetle attack, or infection by mistletoe, and the combined effects of mistletoe and budworm on growth and yield. A serious concern was that current models cannot combine pest effects on tree growth and mortality.

MANAGEMENT INFLUENCES ON FOREST STRUCTURE, AND THE EFFECTS OF FOREST STRUCTURE ON BUDWORM POPULATIONS are also of major importance and need research. The purpose of this effort would be to evaluate stand prescriptions for their effectiveness in reducing the frequency and severity of budworm infestations. Existing budwork-host models, developed to predict the effects of defoliation on the host, can also be used to predict the influence of host condition and forest structure on the pest population.

Finally, there's great concern and needed research to address the EFFECTS OF CHANGES IN FOREST STRUCTURE, DIRECTLY OR INDIRECTLY CAUSED BY BUDWORM, ON SUCH RESOURCE VALUES AS SCENIC BEAUTY, RECREATION, TOURISM, ECONOMIC WORTH, AND PRIVATE PROPERTY. There has been little work on pest effects on these resources in general, and budworm effects in particular. In many portions of the interior West, these resource values may substantially outweigh the worth of timber. The discussion also considered effects of defoliation on timber, forage, water, and wildlife resources. Since budworm defoliation has a minimal impact on forage production and water resources, no research was recommended. However, additional studies were suggested to (A) assess the effects of budworm on the Christmas tree industry, (B) determine the deterioration rates of killed trees, and (C) predict successional changes of vegetation in budworm outbreak areas.

Obviously this is a big order to fill, and judging from the tone of the workshop and the difficulty attendees had agreeing on these priorities, there may be some scientists who feel that the task is still not completely defined. Workshop conclusions are undergoing additional review as Shaw and others develop the problem analysis for research.

The CANUSA connection

As mentioned earlier, scientists plan to structure much of their work around adapting the CANUSA budworm models for use in the Southwest. This would include establishing and validating the relationships which make up a model, and linking it to various resource models such as GENGYM, RUNWILD, etc. (CANUSA was a cooperative effort between Canada and the U.S. to predict the behavior of the western spruce budworm. Its nearly completed models should be available soon as an extension of the Prognosis stand and yield model. See "Prognosis: Fortune Teller for Forest Stands," *Forestry Research West*, June, 1982, pages 1-3).

Shaw believes that some of the information needed to determine these relationships already exists. "What we have to do," he said, "is find out if, in fact, the information is available, how to get our hands on it, and if it's in a format we can use, in concert with our upcoming research."

Forward ho!

Shaw and his group of scientists are planning strategies on three fronts:

1) refine tree- and stand-rating systems that evaluate the intensity of infestations by the budworm in southwestern conifer forests;

2) refine existing systems that quantify the effects of the budworm on tree growth and stand dynamics, and tie these effects to changes in various resource values (i.e., timber, wildlife, scenic beauty, etc.); and

3) add this information to existing stand, growth, yield, and related models to provide forest managers with decision support systems for budworm impact information.

He believes that once these objectives are accomplished, the on-the-ground needs of land managers and other resource specialists that must deal with the western spruce budworm will, in turn, be met.

If you would like additional information on this research, contact Terry Shaw, Rocky Mountain Station, 240 West Prospect Rd., Fort Collins, Colorado, 80526, (303) 224-1251, FTS 323-1251.

Budworm defoliation, such as this "spike-top", is widespread in some areas of the West.

245

Prognosis revisited

by Mike Prouty
Intermountain Station

A crucial part of the 1962 assessment of the nation's timber resources was the prediction of future timber supplies. And although there was a long history of growth and yield research in the northern Rocky Mountains, the assessment effort was not using this information to predict future timber supplies. Disturbed by this lack of applicability, former Intermountain Station Assistant Director Charles Wellner dispatched the Station's Mensurationist, Al Stage, to Washington, D.C. to find out why.

Stage believed the best way to understand the requirements for the assessment analyses was to be an active participant, so he joined the effort and soon learned that the research results lacked generality of scope, and were too diverse in variables used and in methods of application. Yield tables developed by research applied only to even-aged stands consisting of a single tree species, while most stands in the West were comprised of a variety of tree species in a variety of ages.

At the same time, Stage was working with Forest Survey researchers and the Forest Service Northern Region in developing uniform procedures for conducting stand examinations for prescribing silvicultural treatments. Again, it was difficult to forecast how these prescriptions would change future yields.

Research results had not been analyzed with sufficient generality to apply to specific stands. Stage concluded that a forecasting system was needed that was specific to a particular stand and that could incorporate and be periodically updated with research information on growth and yield.

So Stage developed the Prognosis model for stand development, which was described in the June 1982 issue of *Forestry Research West*. Prognosis predicts how stands grow and regenerate under various silvicultural treatments.

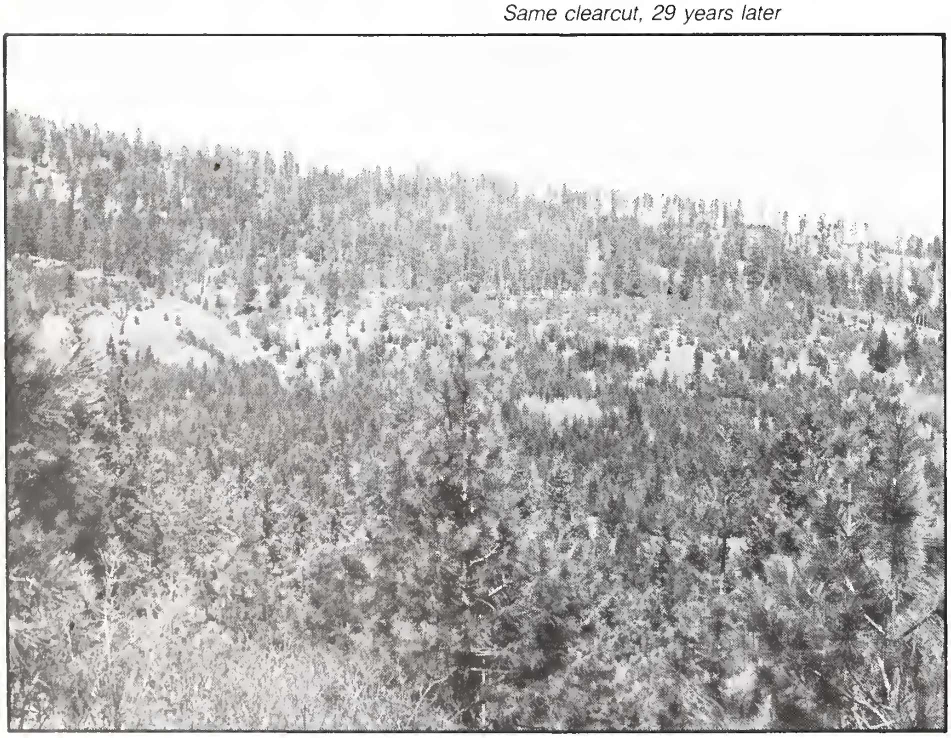
What began as one man's idea has evolved into a research work unit called "Quantitative Analysis of Forest Management Practices," located at the Intermountain Station's Forestry Sciences Laboratory in Moscow, ID, with Stage as project leader. Stage has devoted much of his research career to improving planning information, including Prognosis, and over the years he has recruited a cadre of scientists to assist him in making his model more accessible, more versatile, and more accurate, and thus a more powerful tool for forest managers and planners.

Improving access

As a method of predicting the effect of a variety of management actions on the future development of a stand of trees, Prognosis offers a valuable glimpse of the future. But until recently, this tool was available only to those lucky few who had access to large mainframe computers. The nature of the complicated programming in the simulation model required a computer with immense processing capabilities.

Clearcut, 1906

Same clearcut, 29 years later



The regeneration establishment model allows managers to project future stand development.

Thus, a recent research effort has been to rewrite the extensive Fortran programming to make the model compatible with personal computers and with the Forest Service's Data General (DG) system. A major constraint in the revision was that the biological behavior of the model must not change, and that users would not be required to change their methods or data. This task was led by Research Forester William Wykoff, assisted by Computer Programmer Paul Thomas. After a year of refining, testing, and reprogramming, the task is complete. The program and a draft of the user documentation are avaliable now. Wykoff is presently working on publishing the documentation. With the Fortran 77 version of Prognosis, anyone with a disc drive, a computer with 640K of RAM, a numerical coprocessor, and a compiler will be able to run the model.

In addition to making the model accessible to more users, such as National Forest planners and silviculturists, Wykoff views the completion of the Fortran 77 version of Prognosis as a milestone in another way. Although Wykoff accepts revision as inevitable and necessary in the world of modeling, constant revision and updating make it difficult to ever complete a model and finish the essential documentation for users. He's proud of version 77, because as he states, "The Fortran 77 version of Prognosis is a complete package. We'll have the model itself, and we'll have documentation that describes how to use the model, how it works, and how accurately the model simulates future stand conditions based on real-life data."

Increasing versatility

A Prognosis analysis is built on survey measurements of tree, site, and stand characteristics. The model compiles this inventory, extrapolates it to a stand, then makes a series of projections of stand growth over time. Each projection is based on a silvicultural prescription that the user selects.

Stage and his associates have developed a series of extensions to this base model that increase the ability of Prognosis to represent reality.

The first extension to Prognosis came as a result of a major research effort regarding the Douglas-fir tussock moth. Through the effort of the Pacific Northwest Station and Oregon State University scientists, a model was built—independent from Prognosis—that simulated the effects on single trees attacked by the Douglas-fir tussock moth. A concerted research and development program then combined the models, enabling Forest planners and research managers to assess the consequences of silvicultural treatments and moth control activities on stand volume over time. Two members of the Intermountain Station's Quantitative Analysis research unit, Research Forester Robert Monserud and Operations Research Analyst Nickolas Crookston, were involved in this project and have published a User's Guide for the combined model.

Forest managers realize that regeneration of stands after harvest is critical. Productivity lost by poor stocking or delays in stocking can never be regained. The second extension to Prognosis—the Regeneration Establishment Model—gives managers a tool to evaluate the expected results of regeneration prescriptions and to project future stand development. This extension was developed by Research Forester Dennis Ferguson. It uses the management history of a stand, its site characteristics, and the length of time since the stand was disturbed to generate a new set of tree records to represent regeneration of the site.

The uses of the Regeneration Establishment Model are many. Managers planning to harvest a stand of trees can determine if one or more prescriptions will meet the regeneration objective. If harvest has already occurred, the model can be used to evaluate whether additional stocking effort will achieve desired density levels in the new stand. In addition, the model can be used to establish harvesting schedules and to evaluate regional timber resources.

But what about uses of forests for other than timber management? Clearly, managers need to know how the future structure of forest stands will affect values such as wildlife, scenic quality, watershed, and recreation. To make Prognosis sensitive to this need, Stage and company began work on another extension. Research Forester Melinda Moeur joined the unit, and was given the task of developing the COVER extension to Prognosis. This extension translates tree characteristics as projected by the base model into cover attributes that are significant to a variety of other users of forest stands. The program augments the tree cover with descriptions of the understory shrubs. The model describes how silviculture affects the amount of cover and foliage in the tree canopy, and the height and cover of shrubs, forbs, and grasses in the understory.

With this extension in place, managers can examine the effects of silvicultural treatments on wildlife thermal and hiding cover, on succession and competition with regeneration, and on how canopy and ground cover affecting hydrologic characteristics recover after logging.

Development of additional extensions to Prognosis continues. Stage, Crookston, and others in the research unit are currently testing extensions that will model effects on stand growth and development of depredations by western spruce budqorm, mountain pine beetle, and two common root diseases—laminated root rot and shoestring root rot.

Improving accuracy

Forests, whether managed or not, are under constant attack by a host of agents of disease and death. Whether by slowing growth or by killing trees outright, insects and disease have a profound influence on the future characteristics of stands of trees. No wonder four of six Prognosis extensions that are in place or in final stage of development involve forests pests. By accounting for the effect of insects and disease, these extensions improve the scope of Prognosis forecasts.

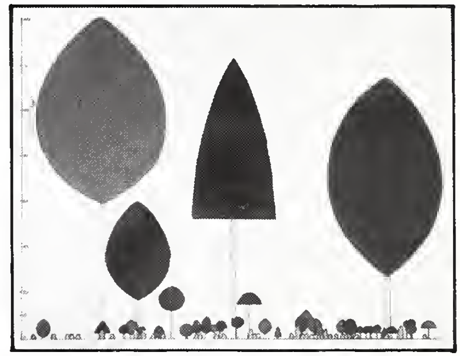
However, from the very beginning, Stage knew that the greatest variability in his model's forecasts would involve natural tree mortality. How does one program a model to predict which trees will drop out of a stand, and when? He and Research Forester David Hamilton have worked to improve the model's accuracy in projecting mortality by identifying factors that increase a tree's chances of death. Using these factors, the model predicts a probability of mortality for trees in a stand.

Stage is not troubled by the inherent natural variability of mortality. A good model reflects reality, and if reality is variable, the model's forecasts also should be. "An accurate model forecasting the sex of an unborn child should be right only half the time," says Stage. "It's a good model, because it accurately reflects reality. Just as such a model indicates we should not go out and buy pink or blue before the birth of a child, our model of mortality in stands implies that we should not be so inflexible in harvest scheduling and road design that this unpredictable mortality cannot be utilized."

Prognosis forecasts are based on actual measurements of a sample of trees that are then extrapolated to represent an entire stand. Like any other model that simulates reality, the quality of Prognosis forecasts relates directly to the quality of the actual data collected as well as the quality and extent of research that supports assumptions used in the model. Stage is particularly proud of the extensive research, and associated publications, that support use of this model.

"A simulation model must make some assumptions about reality, because it's not possible to collect enough data to describe all that goes on in nature. Some models just pull assumptions out of thin air. We've worked hard to substantiate with credible research information any assumptions of reality we make in designing the simulation model. And as research sheds new information about factors on stand growth and development, we incorporate these findings into the model," says Stage.

Pre-treatment, year 1981



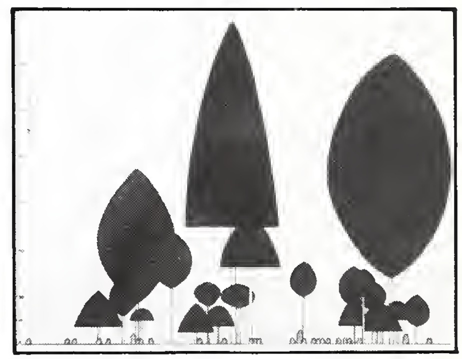
Twenty years after partial cut, year 2031

Alternative B

Partial cut to 80 ft^2/ac in year 2011

YEAR	2011	2031	2081
Trees per acre	21	472	250
Basal area	80	94	129
% Canopy closure	23	37	77
% Shrub cover	42	36	27
Shrub height (Ft)	2.3	2.2	2.2

Partial cut prescription, year 2011



Seventy years after partial cut, year 2081

The COVER model projects effects on the development over time of crowns and shrubs as a result of various silvicultural treatments.

Testing Prognosis was possible because the Intermountain Station has maintained records from permanent sample plots for as long as 70 years. Although these records now include over 100 plots in northern Idaho, another recent effort has been to expand this data base. Forester John Bryne has been given the task of evaluating the existing data to determine what type of new data is needed, and then coordinate with National Forests to locate and establish permanent sample plots that will yield additional data from different ecological situations and new silvicultural prescriptions.

Bryne is enthused about the potential for new data, because National Forests are in the initial stages of establishing permanent plots to monitor silvicultural treatments as prescribed in Forest Plans. "Because we're working directly with National Forest personnel in locating and establishing these plots, we should be able to obtain valuable, long-term data that will be useful in making Prognosis an even stronger tool," said Bryne.

Other additions

Other additions to Prognosis increase the model's capability and versatility. An economic analysis program has been used with the model that allows users to evaluate silvicultural alternatives from an economic point of view. CHEAPO II, developed by Intermountain Station Scientist Erv Schuster, is the latest version of this program that represents a powerful analytical tool for analyzing proposed investments in stand management alternatives.

The Event Monitor is another addition that allows the simulation model to schedule management activities after conditions in the stand meet certain criteria. Before development of this addition, users of Prognosis had to anticipate when future stand conditions would require thinning, for example, and then manually preschedule this activity into the model's projection cycles. The Event Monitor now allows users to specify a set of conditions that must occur, then during the simulation the program will automatically schedule thinning when those conditions are met. Further projections of stand development then reflect the effect of this thinning activity.

Documentation for both the Event Monitor and CHEAPO II has been published and is available. Another "addition" to Prognosis is in development, and promises to add a powerful dimension to the model. To date, Prognosis and its extensions model the development of single stands of trees. But factors that influence the growth and development of forests don't respect stand boundaries. In addition, constraints that restrict or direct forest management —such as watershed or visual quality considerations—can only be modeled at a forest level, not by a single stand.

When documentation is complete, the Parallel Processor extension to Prognosis will allow for the interaction of factors between multiple stands of trees. With this extension, silviculturists will be able to account for the movement of insects from one stand to another. Forest planners will be able to project whether a particular harvesting regime applied to several stands will meet watershed constraints over time.

The Parallel Processor will be used in other ways as well. For example, users will be able to simulate the effect of either performing or not performing a silvicultural treatment on the stand at a given point in time. By allowing "branching," the Parallel Processor will allow simultaneous projections of a stand's development under several conditions, thinned or unthinned for example. Although entailing some of the most complicated programming in the system, this product of Crookston, Stage, and Thomas should simplify assessment of timber resources.

Applying Prognosis

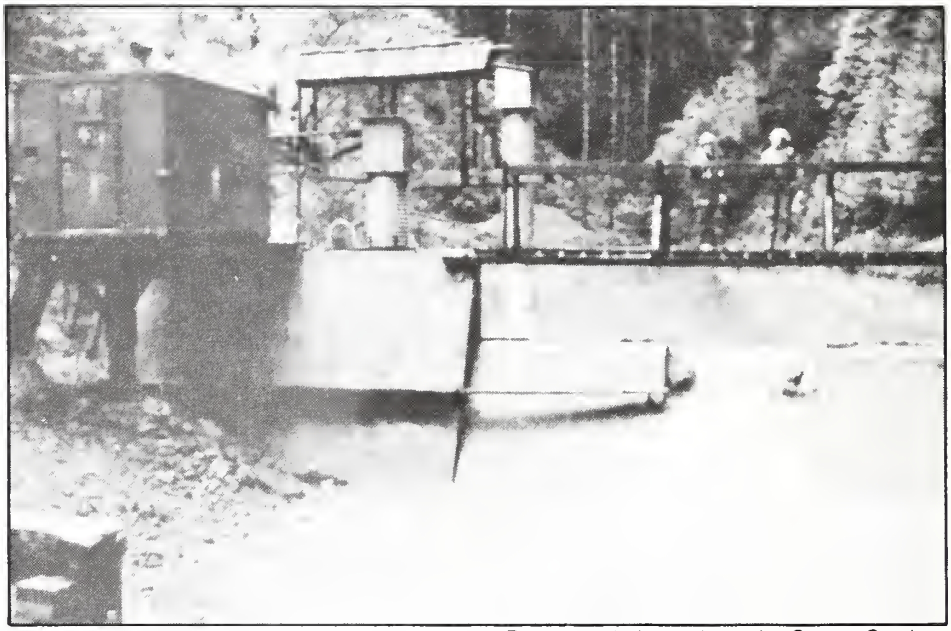
Presently, Prognosis has been used in Forest planning to project growth and yield of forests under prescribed silvicultural regimes. In addition to National Forest use, managers of private timberlands have used the model in timber planning and harvest scheduling corporate forests.

Because the base data for Prognosis were collected from Northern Rocky Mountain forest habitat types, the model's application is restricted to this area. However, an energetic program is under way to expand its use by developing variants of Prognosis based on data gathered from other geographical areas and forest habitat types around the country. A national Timber Management group based in Fort Collins, CO, has developed variants of Prognosis for forest types in California, Alaska, southern Oregon, Utah, Wyoming, southcentral and eastern Idaho, and eastern Washington and Oregon. Although following most of the fundamental design of Prognosis, these variants often differ in respects that depend on the peculiar nature of the growth data available in these regions.

Stage's visitors are greeted with a paper cutout of a wizard's hat taped on his office door. The symbol is appropriate. Prognosis is Stage's crystal ball. And through his work, and through the efforts of the other members of the research unit, their crystal gaze of future growth and development of forests in the West is continually improving. And clearly, their crystal ball is an important tool for everyone involved in managing and planning forest resources.

Caspar Creek: discovering how watersheds respond to logging

by Richard B. Pearce, for Pacific Southwest Station



Data recorded at weirs in the Caspar Creek drainage in northern California are showing effects of logging and roadbuilding on stream flow and water quality.

For the past two decades, researchers from the Pacific Southwest Station, in cooperation with the California Department of Forestry (CDF), have been studying the effects of logging on the integrity of northern California watersheds. Their findings have greatly illuminated the extent and nature of the hydrologic impact, erosion, and stream sedimentation for a northern California basin undergoing a "typical" logging operation.

But forest practices change, and along with them, the definition of what effects need to be measured when judging the impact of activities such as logging. That's why researchers at the Redwood Sciences Laboratory in Arcata, California and the California Department of Forestry, Jackson Demonstration State Forest near Fort Bragg, have launched a second study, this time using current logging practices and a design that should enable them to monitor cumulative, not just isolated, effects. It is hoped that, together, the two long-term investigations will give forest managers, public policy makers, and private enterprise an empirical basis on which to formulate sound logging practices.

Caspar Creek 1962-1976

Based on data from 1962 to 1976, researchers recorded changes in streamflow and sedimentation following roadbuilding and logging at Caspar Creek, located some five miles southeast of Fort Bragg.

Cooperation between CDF and the Station dates from 1962. It has been a fruitful division of labors, with CDF supervising the construction of research facilities, the collection of data, and the logging of experimental watersheds, and the Station designing the experiments and analyzing the data. Together, they have jointly decided upon which studies to undertake and have co-authored several research reports.

Calibrating and treating the watershed

"We started in 1962 with a typical watershed experiment," recalled Project Scientist Raymond M. Rice, during a recent interview. "It was what we call a 'paired watershed' experiment. In this kind of study, you install stream gaging stations in two drainages that are roughly comparable, and monitor both sediment and flow."

The two streams studied were the South and North Forks of Caspar Creek. Both watersheds support growths of redwoods, Douglas-fir, Grand-fir, and hemlock, and had been logged before in the late 19th century.

In the first study, the South Fork was logged using selective cutting procedures typical for that time. The North Fork served as a control.

After a five-year calibration period, logging roads were built into the South Fork area in 1967. The effects of roadbuilding were measured as local on-sight erosion, suspended sediment loads in the stream, and sediment deposited in debris basins. Logging commenced in 1971 and ended in 1973 with the same parameters measured throughout. In all, 60 percent of the timber volume of the South Fork watershed was logged.

Except for a major landslide in the North Fork and an earthen dam break during roadbuilding in the South Fork, Rice, who is a principal hydrologist with the Station, considers the results a paradigm for logging's effects on any Northern California watershed having similar climate, soil, and logging history.

The entire South Fork watershed was tractor yarded between 1971 and 1973.

(The winters in Caspar Creek are mild and wet. In the summer, coastal fog often clings to the watershed until late morning. Annual rainfall is 1190 mm (47 in) with 90 percent falling from October to April. Soil in the area is derived from hard, coarse-grained sandstone and shale, which has been deeply shattered and moderately weathered.)

Effects of roadbuilding and logging on sedimentation

Adjusting the data to account for the landslide and dam break, Rice and co-workers Forest B. Tilley (CDF) and Patricia A. Datzman (PSW) found that stream sediment increased 80 percent with roadbuilding and 275 percent with logging (USDA FS Research Paper PSW-146, 1979).

The researchers observed that most sediment was carried during relatively short periods of high flow. In fact, 81 percent of suspended sediment was transported by flows exceeding 1.23 m^3/s (45 ft^3/s). Flows of this magnitude or greater occur only 1 percent of the time. Recognition of this sediment transport to flow relationship led Rice to concoct the variable $S\bar{Q}_{25}$ as an index of the stream's ability to transport sediment; $S\bar{Q}_{25}$ is the mean rate of sediment discharge in $ft^3/s/mi^2$ that is associated with the top 25 percent of flow volume.

"Most small, steep watersheds are supply dependent," Rice explained, "the water flowing out has enough energy to carry much more sediment than is available for transport. But logging and allied activities stir up the ground and make more sediment available for transport," he said.

Rice suspected that an undisturbed watershed would show only slight increases in suspended sediment loads as stream power increased, and a plot of the sediment/stream power relationship for the north fork of Caspar Creek during the years 1967-76 confirmed this, showing a slow-to-rise curve (Figure 1a).

But when sediment enters the stream because of ground disturbance by road building or logging, sediment discharge increases rapidly with stream power (Figure 1b "disturbance years"). In effect, Rice's data suggest that sediment discharge switches from being mostly "supply dependent" during undisturbed years to being more "stream power dependent" during disturbance years. With more sediment available for transport, sediment discharge becomes more strongly dependent on the ability of the stream to carry sediment.

The bottomline, of course, is that logging and, to a lesser extent, roadbuilding delivered more sediment to the Caspar Creek stream channels than was predicted on the basis of the calibration years.

Extrapolating from stream sediment rates, Rice estimated that if Caspar Creek were logged every 50 years or so, soil in the area would be totally exhausted in 33,900 years.

"That's a planning horizon much beyond what a forest manager needs to consider," quipped Rice. "However," he added in a serious tone, "there is certainly going to be some erosion price to pay when one goes into natural landscapes to take trees; its' just that the price should be prudent and weighed against the commercial benefits."

Effects on stormflows

Another possible consequence of roadbuilding or logging is destabilization of the stream channel because of more or bigger floods. Roadbuilding, even on a moderate scale, might be expected to increase peak stormflow by compacting road surfaces, which would reduce water infiltration, or by channeling water directly into the stream.

However, after reviewing 11 years of Casper Creek flow data, Researcher Robert R. Ziemer found no change in any of several storm flow parameters measured following the period of roadbuilding in the South Fork. The absence of flow effects in Ziemer's data may be explained by the fact that roads occupied only 5 percent of the area. Selective timber cutting and tractor yarding were, however, also found to have no major hydrologic consequences.

Selective timber cutting and tractor yarding were likewise found to have no major hydrologic consequences. By the conclusion of logging, about 15 percent of the watershed had been compacted by roads, landings, or skid trails. Streamflow peaks early in the winter increased three-fold after logging in the South Fork, but were small in magnitude. Storms occurring later in the season—even large ones—were not associated with any change in peak stream flow above the predicted levels. The flood peaks were the same height and the flood volumes comparable between the North and South Forks.

The study suggests that not only was logging relatively innocuous in terms of increasing flow, but further, that the building of skid trails and landings probably did not play a role in increasing even modest run-offs for, if they had, they should have measurably increased flow peaks throughout the year, not just in the fall.

Why did logging affect only Fall storms? Ziemer theorizes that the forested watersheds are initially drier than logged watersheds (trees use more water than no trees) and, therefore, have a greater capacity to absorb moisture. But as soon as soil in the unlogged watershed becomes as wet as that in the logged area, the two perform identically from then on.

In a separate review of the data from Caspar Creek, Rice and co-workers Karen H. Sendek and Robert B. Thomas, found that hydrographs (plots of run-off with time) were shifted forward in time after the area was logged. They found that although peak flows did not change much throughout the year, the logged watershed did respond more quickly to rainfall. "This finding agrees with published engineering studies of agricultural and urban watersheds," Rice said.

Average lag times from storm peak to flow peak decreased by 1.5 hours. Lag times associated with larger storms shortened by as much as 3 hours. The only storms to show an increase in lag time were those occurring early in the season. Since Ziemer had shown these Fall run-off volumes to be high in logged zones, Rice believes it is likely that it was the larger, broader hydrographs that yielded the longer lag times.

Logging roads will be built mid-slope, with cable yarding on the steeper lower slopes and tractor yarding on the gentler upper slopes.

"By creating skid trails, roads and other packed surfaces impervious to water, logging, overall, increases the rate of run-off," Rice said. He added, however, that since the hydrographs were moved forward in time but were unchanged in shape, logging "didn't seem to have an adverse effect on the watershed."

Rice acknowledged, however, that an unwanted impact might be occurring downstream where, for example, tributaries from logged and untouched watersheds join but whose peak flows are normally unsynchronized. After logging, flow at the junction of the two streams could become synchronized with flow effects summing. He noted that the opposite scenario is also a possibility: that synchronized effects downstream could become uncoupled and have some kind of a beneficial effect on lower reaches of the basin.

It's just such complicated interactions between different watersheds and logging activities that Rice and his colleagues are addressing in the second Caspar Creek study.

Caspar Creek: 1985-1994

For the second study the roles of the two watersheds have been switched. The now-stabilized South Fork will be used as a control while, in the North Fork, separate catchments will be clearcut, clearcut and burned, or left unlogged. As in the first study on the South Fork, 60 percent of the trees will be removed.

"The move to clearcutting reflects a change in silviculture practices," says Rice. "Foresters weren't getting the growth rates and regeneration they expected with partial cutting," he said.

Another difference will be the predominant use of skyline yarding to harvest trees. Less than 30 percent of the timber volume will be removed using tractors, and then only on gentler slopes. This change should lead to much less ground disturbance and soil compaction than occurred when the South Fork was logged.

As in the first study, researchers will be monitoring storm sediment discharge and stream flow parameters before, during, and after roadbuilding and logging. However, their study methods and equipment have been improved since the 1967-76 experiment. For one thing, statistician for the group, Robert Thomas, has been able to develop a new sediment sampling technique that yields very accurate estimates of sediment discharge.

"Past analyses of stream suspended sediment yields underestimated actual values by as much as 50 percent," Rice said.

Other improvements include the addition of 13 stream gaging stations, each under microprocessor control (waterlevel recorders provide back-up should the microprocessor fail or be damaged).

Just as logging practices and measurement techniques have changed since the sixties, so too have definitions of effects which are of interest to the public and the subject of regulations.

"This time," notes Rice, "The Caspar Creek study will be designed differently, owing to a number of legislative initiatives. Forest practice rules have changed substantially," he said.

The new requirements were placed on forestry by the National Environmental Policy Act (NEPA), and the Clean Water Act (PL92-500). The latter Act, passed in 1972, mandates the development of plans to reduce non-point source pollution from activities such as timber harvesting. NEPA directs governmental agencies to consider cumulative effects of pollution when assessing environmental impacts.

Cumulative effects

"A cumulative effect," explained Rice, "is when one acceptable activity interacts with another acceptable activity and produces something unacceptable."

As an example, Rice gives the hypothetical case of a factory that discharges organic pollutants into a stream at acceptable concentrations but when the compounds are taken into a water treatment plant downstream, they are converted into harmful chlorinated compounds in concentrations that exceed water-quality guidelines.

"It is conceivable that cumulative effects may occur in a watershed basin subsequent to activities like freeway construction, farming, or logging," Rice said.

In spite of sediment dilution over distance, Rice sees the possibility for adverse scenarios. For instance, it's possible that small, high-gradient watersheds subjected to logging might transport sediment to another stream with less power, where the sediment settles out, possibly lessening the quality of habitat for spawning fish.

In the new study, Rice and colleagues will be measuring sediment in watersheds where no activity is taking place, watersheds where a portion is being clearcut, and those with parts clearcut and burned.

"We will be testing the hypothesis that if there are cumulative effects, disturbance of a given proportion of an upstream watershed will have less impact than will the same proportion of disturbance to a larger downstream watershed," Rice said. "If the sediment delivery from one area is interacting with the sediment delivery from another and the effects are picked up downstream as a joint effect that's greater than would have been expected from analysis of a similar smaller watershed, then cumulative effects will have been demonstrated," he explained.

In addition to sediment changes after roadbuilding and logging, scientists will be looking for changes in the timing of storm run-off as well as possible effects on fish habitat and populations.

"We got our first year's data last winter. We'll get more calibration data in '87, '88, and '89 and then we will log the area and run the experiment for another four years or so to see how it's performing," Rice said.

Planned studies on fisheries

Concurrent to the cumulative effects studies, Fishery Biologist Lynn M. Decker will be studying the effects of logging on fish habitat and survival.

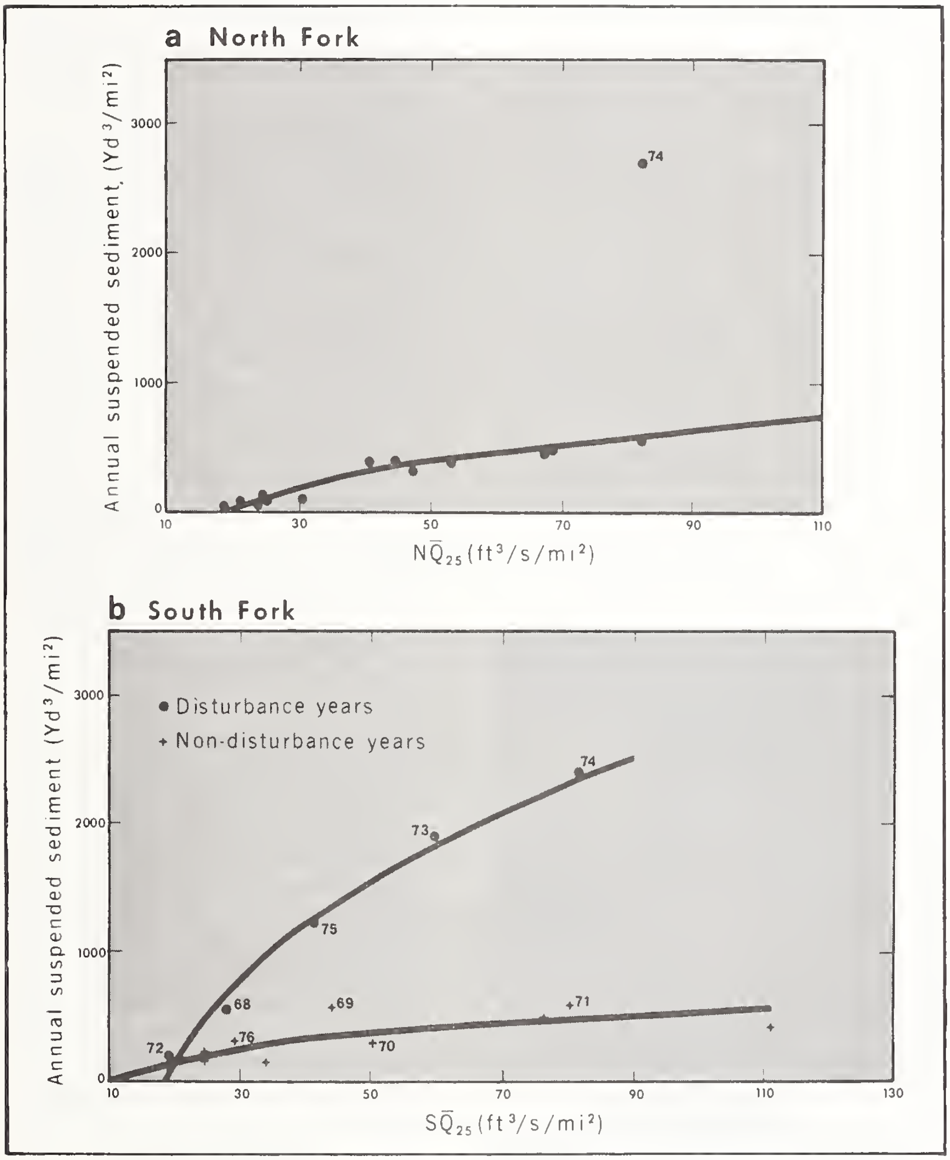
"The impact of logging on steelhead and salmon is an important issue and always has been," says Decker.

However, it's difficult to link directly the effects of watershed processes to fish survival because of the multitude of indirect physical and biological factors that can affect the number of fish produced and whether or not fish will reach the smolt stage. "How does one account for bad years in the ocean, or fishing pressure on what we see on-site in the stream?" Decker asks.

In an effort to answer this question Decker has introduced fish in equal numbers into both forks of Casper Creek and will watch how they respond to the habitat area and volume available to them before, during, and after logging.

"We are assuming that the fish at Casper Creek will stay or leave, depending on the quality of the habitat," Decker said.

One way logging could reduce habitat is by introducing large amounts of sediment into a stream. Pools could fill, reducing habitat volume. Alternatively, sediment could alter the quality of the stream bottom. "I've learned from some of my earlier work that coho salmon tend not to spend as much time in sandy bottom pools as they do in ones with coarser substrates," Decker said.



Annual sediment discharge of the forks as related to stream power as indexed by $\bar{Q}_{25}$ (the mean discharge for the top 25 percent of the flow volume).

The effects of logging on fish survival may not be all detrimental, however.

"One of the direct effects of logging may be that trees get knocked into the stream channel and streamflow scours even more good habitats," Decker observed.

To follow the movement of fish in and out of Caspar Creek's two forks on a day-to-day basis, Decker has installed wire box traps to monitor upstream and downstream movements of fish in the study sections.

"At any point in time I will know the total number of fish in each of the creek's sections," she said. Fish numbers and survival will be correlated with sedimentation, hydraulic, and habitat data before, during, and several years after logging.

By the end of the Caspar Creek study in the middle of the next decade, there should be a sizeable quantity of data from which conclusions can be made regarding the short- and long-term effects that modern logging practices have on fish habitat availability and quality. Along with the findings on sediment discharge and flow effects, the research project promises to provide valuable new insights into the multifaceted, and often surprising, effects of man's removal of timber from forests. The most important of these may be findings related to cumulative watershed effects.

More details are available in *A Watershed's Response to Logging and Roads: South Fork of Caspar Creek, California, 1967-1976*, Research Paper PSW-146. Copies are available from the Pacific Southwest Station.

245

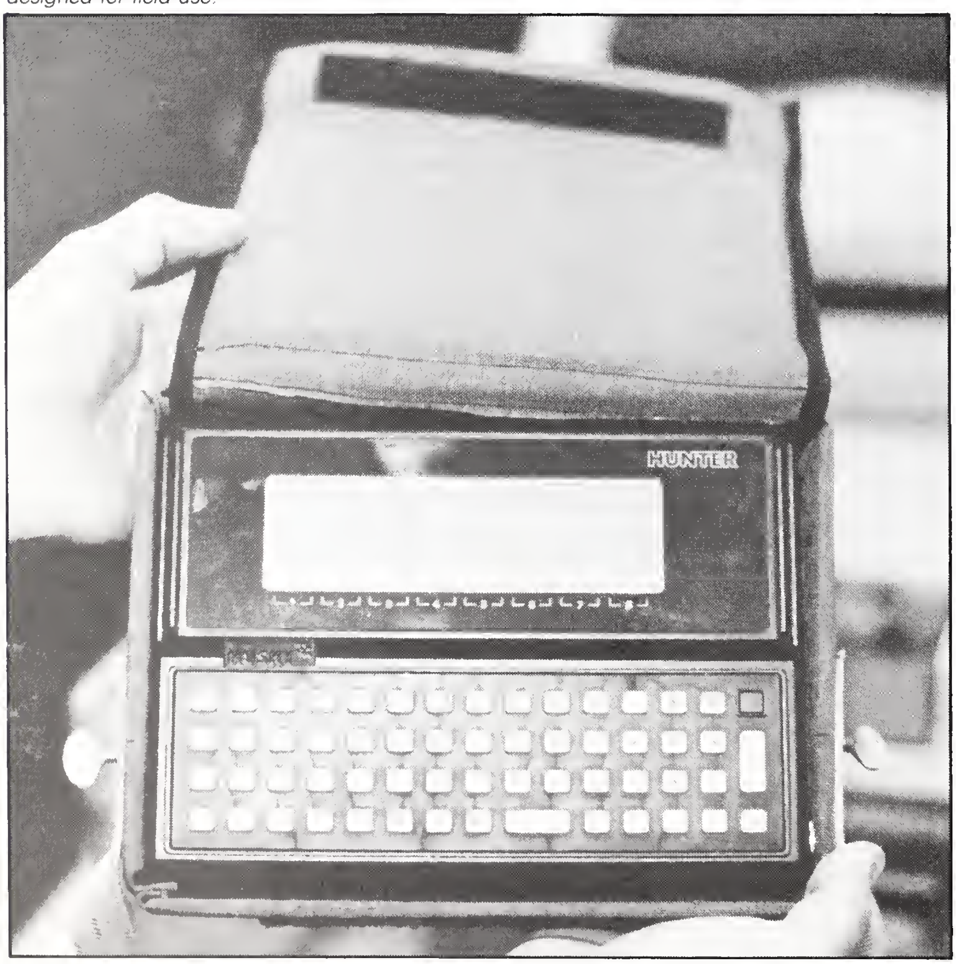
Hand-held data recorder changes inventory system

by Dorothy Bergstrom
Pacific Northwest Station

Finding a programmable data recorder suitable for field use triggered changes in data-handling that have resulted in a more efficient system for conducting the periodic inventory of forest resources on private land in Oregon, Washington, California, Hawaii, and the western Pacific.

According to John Poppino, leader of the Pacific Northwest Station research unit responsible for conducting periodic forest inventories, the new system is proving satisfactory beyond anyone's expectations. "The spectacular change is based on the willingness of our data-collection staff to throw away the pencil and learn how to convert the tally card to a computer program for the data recorder," he says.

The Husky Hunter in a cloth carrying case designed for field use.



The essential change is that data-collection crews record directly into recorders and do the initial editing for erroneous codes and missed data before they leave the plot. "When they leave a plot, they can be confident they have done a good job," Poppino says. At the end of the day, back at the motel, they transfer the data to a microcomputer for additional editing and transfer to a diskette that is then returned to the lab in Portland, where the compilation and analysis are done and reports are written.

Although forest inventory units in other parts of the country are working with data recorders, the Pacific Northwest Station is the first to evaluate a broad range of recorders for field use and the first to have an alpha-numeric data-capture editing program.

The new system is faster and less expensive than the old one, Poppino says. Putting data directly on recorders eliminates keypunching and the chance for making errors in copying. This move alone saves time and reduces costs. Because clean data are available for analysis sooner, accurate information is available earlier to analysts, economists, forest planners, and others who need facts about conditions on private forest land. A process that used to take more than a year can now be done in a few months and in the future may be shortened to weeks.

The key to success of the new system, Poppino says, was the decision to make the data-collection crew responsible for giving clean data to the computer applications group. This meant learning how to program the computer. "But almost as important," he says, "has been the fringe benefit of job enrichment, as people have been allowed to restructure their jobs."

The data recorder that triggered the change was discovered by Poppino in the spring of 1984. At a professional meeting, he saw a programmable instrument that looked promising. The idea of recording data directly into recorders in the field had been discussed for some time, but until then no appropriate instrument was available.

The Forest Inventory and Analysis staff had already identified the characteristics needed in an instrument suitable for field use. In addition to meeting standards for technical capability, the instrument had to be easy to operate and require a minimum of training time for users. It also had to be stable and durable under the conditions encountered by data-collection crews; for example, it had to be shockproof, waterproof, and dustproof. It had to be light enough to carry all day and small enough to fit in the pocket of a cruiser's vest. The batteries had to last at least a full day and be easy to change.

After seeing what he considered a candidate recorder at the meeting, Poppino asked one of his staff to find out where to borrow the instrument for examination. In a short time, the staff member was conducting a full-scale test to rank 12 programmable data recorders against a list of characteristics needed for fieldwork.

Only one instrument ranked high in all characteristics. It was the instrument that had impressed Poppino earlier—the Husky Hunter, built in England and originally designed for British Army gunnery exercises. It weighed about 2½ pounds. It could be programmed to store and edit data; store codes; calculate slope, distance, and tree heights; convert English measure to metric units; and do all the other tasks required. It also permitted editing on the plot and could be hooked up to other equipment that would print out data and transmit them to another computer. The cost was reasonable. The Forest Inventory and Analysis unit bought several instruments for trial.

Writing program

Although none of the data-collection staff was experienced in programming, Poppino assigned them that responsibility. He was convinced that their intimate knowledge of how to collect data could not be duplicated by others and that they could be trained to program the data recorder. "We wanted to program the instrument to help with the job, rather than expecting the data collectors to adapt to a computer program written by non-experts," he said. So the people who tramped the forest, got stung by bees, and slipped on wet vegetation, learned how to instruct their new electronic servant. They figured out how to create a plot card on the computer and how to write a program that would also monitor their work, remind them of items they might miss, and refuse to cooperate if they tried to enter data in the wrong code or record measurements out of scale.

By taking on the responsibility of handing "clean" data to the people who compute statistics, analyze data, and eventually write reports, the data-collection staff carried the inventory process several steps beyond what used to be done. It wasn't easy. They added computer stress to the physical hardships they were used to, but in the process they added excitement to their jobs and the satisfaction of meeting new challenges. They not only created a much better product, but they learned new skills and took on new responsibilities that are still expanding.

How they do it now

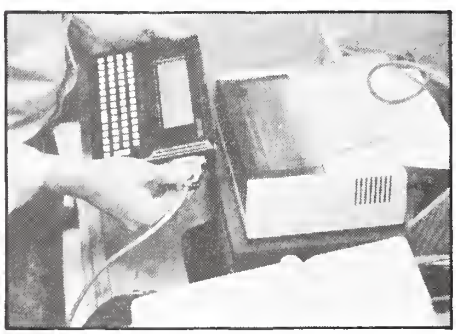
As a result of the new system, forest inventory is now considered a year-round job. In the past, when early summer arrived, there was a push to get into the field and collect data, but the tally cards often piled up in the office while work on ownership data and analysis of aerial photos was being done. Now, crews do not head for the field until all preparations have been made.

"The end is not in sight," says Poppino, "the process is continuing as the data-collection staff explores new applications for the data recorder and their skills as programmers." Already they have begun work on computer programs to use the data recorder to organize information from aerial photos in the lab and to take it to the county courthouse and use it for collecting and verifying data on plot ownership.

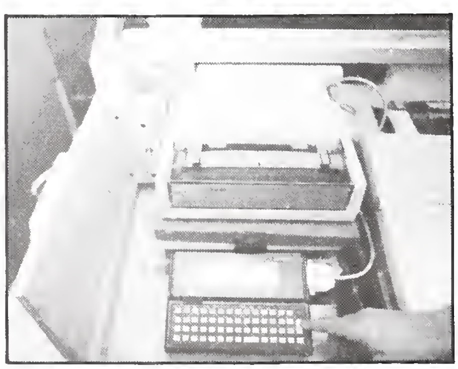
The travel case serves as a portable work station, about 2 feet wide and 2 feet deep. It fits on top of most motel furniture and in the back of a vehicle similar to a Blazer or Jeep. When loaded, it weighs less than 40 pounds.

Foam padding secures equipment: a microcomputer and power converter, a printer and supply of paper, a power-surge protector, software user manuals, extra batteries, and extra diskettes.

One outlet supplies enough power to run the system.



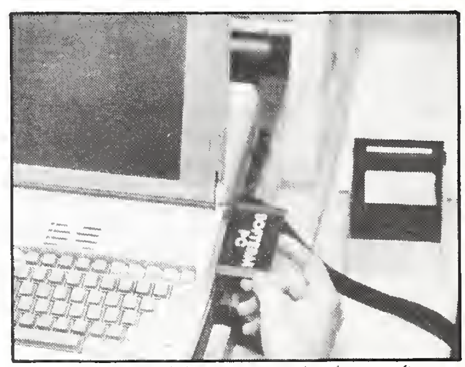
At the motel, the Husky is connected to the printer.



Field plot data are printed.

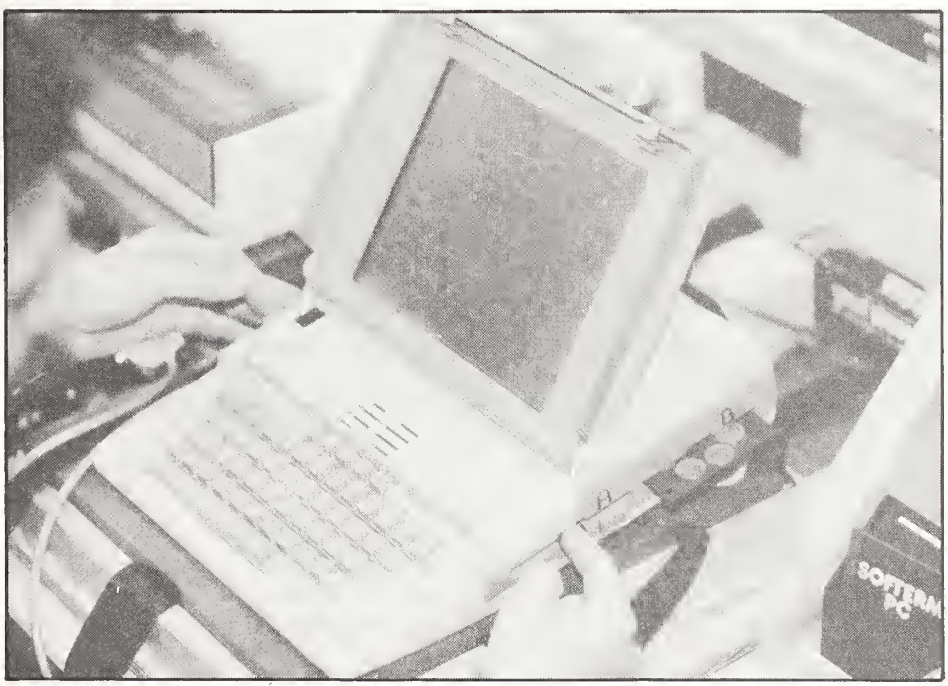
The printed copy is reviewed, and comments that might be helpful are added.

Separate cables connect the three pieces of equipment and must be hooked up correctly.



A diskette containing communications software is inserted into the microcomputer to allow transfer of field plot data to the microcomputer.

A diskette that will hold 2 weeks' worth of field plot data is loaded into the microcomputer for transfer of data from the Husky to the microcomputer and filing on a separate diskette.



After files are transferred from the Husky to the microcomputer, a backup copy of the diskette is made.

Poppino credits his entire staff with willingness to break out of familiar routines and move creatively to improve the inventory system, in the wake of the data collection staff's pioneering work to produce a practical computer program for collecting and editing data.

Certain individuals on the data-collection staff have been particularly creative and have played key roles, according to Dale Baer, their supervisor. Bruce Hiserote was responsible for the initial attempt at programming and is now improving the field data-collection programs. Jim Harrow planned and conducted the test of candidate data recorders and is doing additional programming for recording ownership data. Steve Hiebert designed the cloth carrying case for the Husky. Jeff Jenkins designed and built the portable wooden equipment case. Barbara Beil is developing programs for recording photo interpretation data. and Jim Hildreth has developed a program for recording the map point data.

Poppino thinks the programmable, portable data recorder will become an important tool for workers in other disciplines, who are already exploring possibilities. These include geneticists, silviculturists, forest consultants, and people who work in presale inventory.

The new inventory procedure has not yet been described in the technical literature, and Poppino and his staff welcome inquiries about the inventory procedure or performance of the data recorder. They can be reached at 503/231-2249 or 503/231-2117, FTS-423-2249.

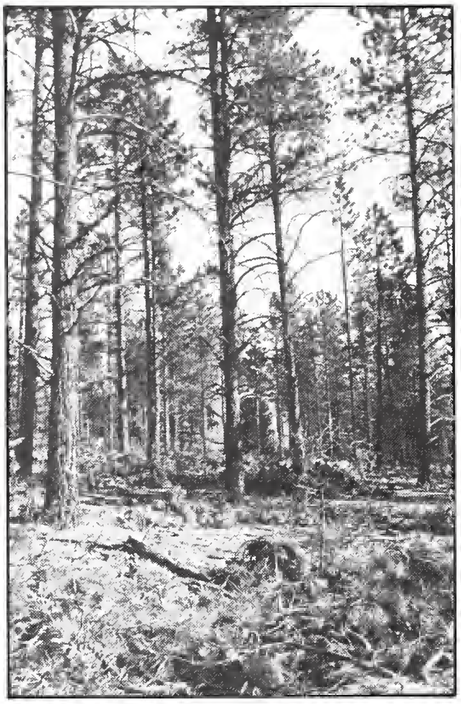
New Publications

Fuel loading and fire behavior

Surface fuel loading is an important component of mathematical models that predict fire behavior. In a new Intermountain Research Station publication, Scientist James Brown reports a great deal of variability of surface fuels with vegetation types. According to Brown, the implications of this finding is that managers need not spend time and money devising ways to appraise fuels for large scale planning efforts—just a few fuel models are needed to appraise fire behavior for broad vegetation types.

However, Brown points out that when managers are planning specific activities, such as a prescribed burn, they can't rely on broad fuel models to accurately portray the situation. In such instances, visits to the site are necessary to accurately appraise fuel loads.

Persons modeling fuels and fire behavior will find the fuel loading data and discussion of mean and median loading contained in this publication to be helpful.



To obtain a copy of the report, request *Surface Fuel Loadings and Predicted Fire Behavior for Vegetation Types in the Northern Rocky Mountains*, Research Note INT-358.

Forest manager's guide to western spruce budworm

Managing Trees and Stands Susceptible to Western Spruce Budworm is a guide for detecting and evaluating effects or potential effects of the western spruce budworm in managed forests. It provides methods for comparing management strategies, and support for making budworm-related decisions. The book focuses on the effects of budworm on trees and stands, and outlines operations for detection, evaluation, and control. It uses a new approach to managing budworm problems that includes direct suppression, but emphasizes forest management to reduce susceptibility.

Chapter 1 looks at historical factors affecting forest health and productivity, including fire, logging, and insects and disease. Other chapters discuss the western budworm, its life history and hosts, and natural regulating factors. The effects of budworm infestations, susceptibility of sites and stands, and the role of the insect in forest succession are examined. Survey and sampling methods for population and damage assessment, detection, and evaluation, and different methods for rating the hazard of stands to western spruce budworm are also discussed.

Of particular interest to forest managers are Chapters 7 and 8. Chapter 7 looks at tactics for dealing with budworm in western forests, including direct application of chemical or biological agents, and indirect manipulation of the budworm's habitat—the forest. In Chapter 8, decisionmaking processes for selecting these management tactics are discussed, and step-by-step case studies are provided.

Western Spruce Budworm and Forest Management Planning, a related management guide for forest planners, is in the process of publication. Full documentation for the underlying concepts and current theories related to budworm will be provided in *Western Spruce Budworm* (also soon to be published), which is a synthesis of current knowledge about the insect and its hosts. It provides the technical and scientific background for the recommendations in both guides.

To request *Managing Trees and Stands Susceptible to Western Spruce Budworm*, contact the Pacific Northwest Research Station for Technical Bulletin 1695.

Shelterwood regeneration of true fir

Natural regeneration has some significant short-term disadvantages, including lack of stocking control and uncertainty of timing. Therefore, planting has become the dominant method of regeneration in California and elsewhere. However, natural regeneration is clearly an option if the planning, economic, or legal disadvantages (arising from uncertain timing) can be resolved.

Natural regeneration of true fir forests has been the focus of research at Swain Mountain Experimental Forest, in northeastern California, since 1958. This Forest covers 5,998 acres and occupies essentially all of Swain Mountain, an asymmetric volcanic cone with a steep southern face, covered by an old brush field planted to Jeffrey pine, and long, gentle slopes covered by old-growth true fir forests on the other exposures. One study, using small shelterwood blocks, was started in 1970 and 3-year results were published in 1979. Those results have been extended through 1978, providing several useful findings.

For instance, scientists observed that, if leave trees are carefully chosen for their capacity to produce seed and to remain standing after a shelterwood cut, as few as 10 trees per acre were adequate to regenerate old-growth stands of red fir and white fir. Additional trees simply make protection of the established regeneration more difficult during removal of shelterwood. In addition, if the shelterwood is left standing for more than 4 years, regeneration suffers less under 10 trees per acre than at the other levels tested.

Their findings also show that in areas like Swain Mountain, where the forest cover is a mixture of red and white firs, regeneration is likely to be predominately red fir, even if red fir represents only a minor component of the shelterwood.

Clearly, the establishment of seedlings did not follow the general pattern of cone production on Swain Mountain Experimental Forest which suggests that, if appropriate seed trees are chosen, it may not be necessary to schedule harvesting or site preparation to coincide with a "good" seed year. However, before any realistic conclusion can be drawn, actual data must be collected on seed production patterns in shelterwoods.

Details are in *Shelterwood Regeneration of True Fir: Conclusions after 8 Years*, Research Paper PSW-184, available from the Pacific Southwest Station.

Timber resource statistics for California

Five publications, concisely highlighting timber resource information for California, are now available from the Pacific Northwest Station. Each report presents information by subregional resource area.

Tables in the reports cover total forest area, timber volume, growth, and mortality data. Timberland area, species composition, general stand types, and land ownership patterns are briefly highlighted, and each report also contains a short discussion of inventory procedures and reliability of inventory data.

Timber Resource Statistics for the North Coast Resource Area of California (Resource Bulletin PNW-131) provides statistics for Del Norte, Humboldt, Mendocino, and Sonoma Counties. The north coast resource area contains an estimated 3.6 million acres of timberland with 13.8 billion cubic feet of standing timber—about 25 percent of the State's growing stock. For over three decades, the North Coast has produced 35 to 40 percent of the State's industrial wood products.

Timber Resource Statistics for the San Joaquin and Southern California Resource Areas (Resource Bulletin PNW-132) deals with two resource areas containing over half of the State's land area, yet only 15 percent (2.4 million acres) of its timberland. Growing stock inventoried for these areas, which encompass Alpine, Amador, Calaveras, Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Madera, Mariposa, Merced, Mono, Orange, Riverside, San Bernardino, San Diego, San Joaquin, Stanislaus, Tulare, and Tuolumne Counties, is estimated at 8.5 billion cubic feet.

Timber Resource Statistics for the Central Coast Resource Area of California (Resource Bulletin PNW-133) provides statistics for Alameda, Contra Costa, Marin, Monterey, San Benito, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, and Ventura Counties. Total growing stock volume is estimated at 2 billion cubic feet on about 340,000 acres of timberland.

Timber Resource Statistics for the Sacramento Resource Area of California (Resource Bulletin PNW-134) provides information on 4.2 million acres of timberland containing 15 billion cubic feet of growing stock. About a third of the Sacramento resource area is timberland. Counties inventoried for this report were Butte, Colusa, El Dorado, Glenn, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Sierra, Sutter, Tehama, Yolo, and Yuba.

Timber Resource Statistics for the Northern Interior Resource Area of California (Resource Bulletin PNW-135) reports statistics for Lassen, Modoc, Shasta, Siskiyou, and Trinity Counties. The northern interior resource area contains 16 billion cubic feet (29 percent) of California's timber volume, and about 35 percent (5.2 million acres) of the State's timberland. The Northern Interior area accounts for 25 to 30 percent of the State's timber production, second to the North Coast area.

The Pacific Northwest Station, as part of the nationwide Forest Inventory and Analysis project, is responsible for timber inventories in California, Hawaii, Oregon, and Washington. Information in these five publications was collected during inventories conducted from 1981 to 1984.

For copies of the reports, contact the Pacific Northwest Station.

Testing avalanche runout equations

The maximum runout distance for snow avalanches is a matter of great concern in populated mountainous areas. Residents usually have learned to cope with the "normal" avalanches at known sites. However, the infrequent, long-running avalanche can cause heavy damage because it invades areas previously considered safe. Runout distances are also important in uninhabitated areas where transportation routes and recreational areas can be threatened.

The Norwegian Geotechnical Institute recently developed a set of emperical equations for predicting maximum avalance runout distances. However, these equations are for the Norwegian climate and terrain, and never were tested for other areas—until now.

Research out of the Rocky Mountain Station has found that the Norwegian predictions are sometimes incorrect for avalanches in other locations. Studies conducted in North America and Switzerland show that although the equations predict well for most paths, they consistently underestimate runout distance for certain types of paths, such as those with a longitudinal profile shaped like a hockey stick, i.e., a slightly concave track that changed abruptly to a flat or near flat runout surface.

Details on these findings and new equations that were developed from the test data are available in the reprint *A Test of the Avalanche Runout Equations Developed by the Norwegian Geotechnical Institute.* Copies are available from the Rocky Mountain Station.

Son of CHEAPO

Since its introduction in 1979, CHEAPO, a computer-based economic analysis program, has allowed users of the Stand Prognosis Model to evaluate silvicultural alternatives from an economic point of view. However, recent modifications to the Prognosis Model have rendered CHEAPO obsolete.

Now a new Intermountain Station report provides a user's guide for a new computer model, CHEAPO II. The new program allows users of the Prognosis Model to analyze the economic aspects of management treatments projected by the latest version of the Prognosis Model and its associated extensions: the Regeneration Establishment Model and the Douglas-fir Tussock Moth Outbreak Model.

CHEAPO II is designed to allow flexibility in the types of stands that can be analyzed, the types of management regimes analyzed, and the types of economic analyses undertaken. It represents a powerful tool for analyzing proposed investments in stand management alternatives.

Request *User's Guide to CHEAPO II—Economic Analysis of Stand Prognosis Model Outputs*, General Technical Report INT-211.

Grizzly bear habitat symposium proceedings

The Interagency Grizzly Bear Committee (IGBC) was established in 1983 to coordinate research and management of grizzly bears in the lower 48 states. The IGBC sponsored a Grizzly Bear Habitat Symposium on April 30-May 2, 1985 for scientists and managers to share information and develop better understanding of habitat management for grizzly bears. Over 350 participants from land management agencies, industry, universities, and Federal and State research organizations traveled to Missoula, MT, to attend.

An Intermountain Research Station report provides the proceedings of this symposium. The report contains 33 papers and three abstracts including state-of-the-art information on grizzly bear habitat delineation and management. Topics are general habitat concerns, considerations, and conditions; mapping and evaluation; habitat improvement and coordination; and cumulative effects of activities on habitat.

Request, *Proceedings—Grizzly Bear Habitat Symposium*, General Technical Report INT-207.

Preventing fire retardant corrosion

Fire control agencies in the United States use millions of gallons of fire retardant annually in the suppression of wildfires. The chemical salt solutions used as fire retardants corrode metal. This corrosion can destroy the equipment used for mixing, storing, and applying fire retardants, resulting in loss of hundreds of thousands of dollars every fire season. In addition to the economic loss, corrosion of equipment, particularly aircraft, can create safety hazards.

A new Intermountain Station report provides guidelines to help those who operate and maintain airtankers and ground support equipment to fight corrosion. The guidelines contained in this four-color report describe the corrosive action of fire retardants and tell how to control or minimize corrosion of airtankers and ground support equipment.

To obtain a copy of this report, request *Guidelines for Preventing Fire Retardant Corrosion*, General Technical Report INT-210.

Using indicator plants to assess susceptibility to the fir engraver beetle

In the environmentally diverse forests of northern California, the indicator plant approach has shown promise for productivity assessment. Because of the typically long, dry summers in northern California, trees may often undergo high moisture stress, and plant indicators of site xericity or "droughtiness" could be a particularly useful management tool.

Griffin identified indicator plants to develop a Vegetation Drought Index (VDI) for forests in the Pit River drainage of the Cascade Range in northern California. VDI, expressed as the average of the drought values of the indicator species found on a plot, ranged from 3.0 (least xeric) to 6.7 (most xeric). Because most useful indicator plants could be found on most sites even after drastic disturbances, the VDI for a site should remain relatively constant over time.

Trees under high moisture stress are generally more susceptible to insects and diseases, suggesting that a VDI may predict susceptibility to these pests.

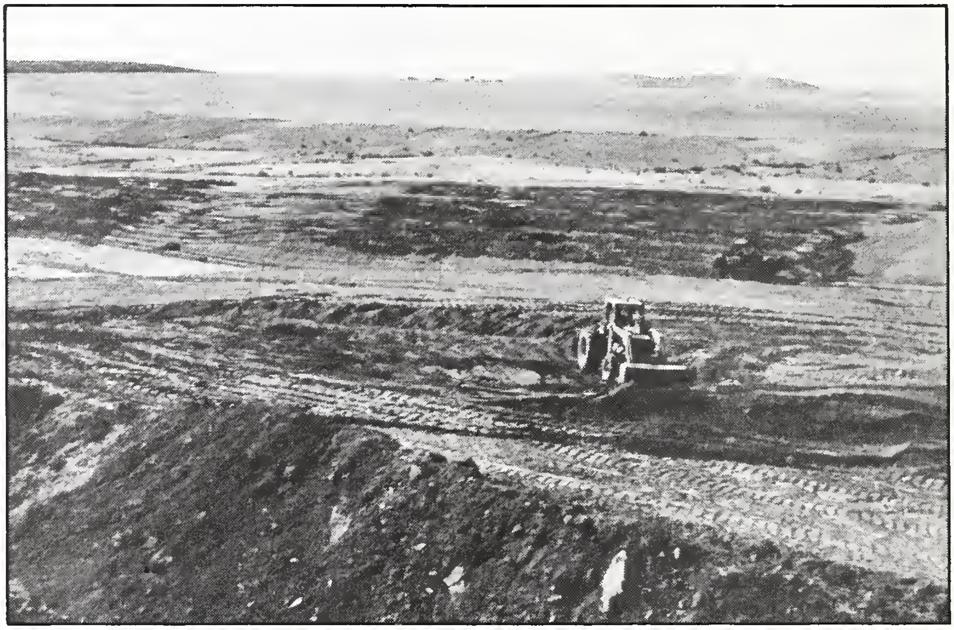
Pacific Southwest Station Entomologist George Ferrell used VDI to estimate the susceptibility of California red and white firs to the fir engraver beetle (*Scolytus ventralis*). This bark beetle attacks and kills true firs (*Abies* species) throughout much of western North America, and droughts often result in outbreaks that cause widespread tree mortality. Their evaluation was carried out for northern California forests where these true firs (*Abies* species) occur in mixed conifer and true fir stands. Midway through the summer drought, true fir moisture stress—a known predisposing factor—was highest on sites with highest VDI values (most xeric). In mixed conifer stands, the susceptibility of white firs—as indicated by the mean percentage of their basal area killed annually—was highest on sites with highest VDI values. But in true fir stands, the susceptibility of mixed red and white firs was highest on sites with the lowest VDI values.

The contrasting results from the mixed conifer and true fir stands may have been attributable to differences in site xericity. Based on their VDI, the mixed conifer sites were more xeric (range 3.6-5.1) than were true fir sites (2.3-3.7). Differences in the degree to which site xericity determine stand susceptibility to the fir engraver are probably attributable to the site elevations.

The results suggest how plant indicators of site xericity might be used to predict susceptibility of true firs to the engraver in mixed conifer and true fir stands in California. Indicator plants will have to be developed for other regions in California before the use of VDI can be evaluated for them. Regression models with VDI, stand basal area, and percentage of true fir as regressors lacked the required predictive range and precision, suggesting that VDI will likely have to be used in combination with predictors other than, or in addition to, those analyzed.

Additional information is in *Using Indicator Plants to Assess Susceptibility of California Red Fir and White Fir to the Fir Engraver Beetle*, Research Note PSW-388. The Pacific Southwest Station has copies.

Sawdust helps reclaim bentonite spoils



Success at reclaiming bentonite mine spoils in the Northern Plains does not come easy. One of the main obstacles involves the infiltration rate of water into plant growth media. Precipitation is sparse in this region, and when it does fall, little filters into the hard clay spoils.

Scientists at the Rocky Mountain Station have found that amendment of sawdust into the spoils can increase the infiltration rate up to 300 percent over non-amended spoils—a mean infiltration rate that is only slightly lower than the mean for all range-soil groups in the Northern Plains.

Studies show that other amendments such as gypsum and inorganic fertilizers were not as effective as sawdust.

If you would like more information, write the Rocky Mountain Station and request the reprint *Infiltration Rate of Bentonite Mine Spoil as Affected by Amendments of Gypsum, Sawdust and Inorganic Fertilizer*.

U.S. GOVERNMENT PRINTING OFFICE 1987 776-033/65200

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Pacific Rim markets for construction-grade logs

Markets for small, lower-grade softwood roundwood logs will expand steadily through 1995, according to *Potential Pacific Rim Demand for Construction-Grade Softwood Logs* by Donald F. Flora and Richard P. Vlosky, Recently published by the Pacific Northwest Research Station.

The publication attempts to answer questions about supply and demand for construction-grade logs in a multi-country Pacific Rim geographic context. Principal suppliers within the Pacific Rim are Canada, Chile, New Zealand, the United States, and the Union of Soviet Socialist Republics. Expected purchasers are China, Japan, Korea, and Taiwan.

According to the research, construction-grade logs compete with U.S. number 3 coastal hemlock saw logs, 6 to 12 inches in diameter; radiata pine from Chile and New Zealand; and all but the largest Soviet softwood logs from eastern Siberia and the Soviet Union Far East.

Projections of demand and supply for construction-grade logs were estimated for 1990 and 1995 for each supplying and consuming country around the Pacific Rim. After adjustments for transportation costs, exchange rates, and inflation, these separate supply equations were summed to provide an aggregate Pacific-wide supply function. A similar process was applied to demand.

According to the research, log supplies will lag slightly behind demand until 1990, generating about a 10-percent increase in prices, which are expected to be level thereafter. United States exports of construction-grade logs are projected to increase 35 percent by 1990, and another 23 percent by 1995.

The Pacific rim market for construction-grade logs is projected to expand significantly through 1995, with demand outpacing supply until 1990. For the subsequent half-decade, supply and demand should shift together.

Economic conditions in each country affecting the supply of (or demand for) construction-grade logs are discussed, along with assumptions made for each country. Composite results for the Pacific Rim, which determine estimated Rim-wide prices and log flows, are covered in the final section. More economic detail for each country considered is available in the appendix.

For more information, request Research Paper PNW-364 from the Pacific Northwest Station.

Patch cutting and the water balance

Scientists at the Rocky Montain Station have completed plot studies in a Colorado subalpine forest that tested the effect of patch clearcutting on water balance of the site. Although many studies have demonstrated that openings in the forest canopy do increase snow accumulation and streamflow, this latest research was designed to: (1) investigate the effect of a forest opening on the accumulation and melt of the snowpack in both the opening and in the surrounding forest; (2) determine if there are any differences in soil moisture recharge between the forest and the opening; and (3) quantify the evaporative components of the hydrologic cycle for a specific site, to determine how the creation of a small opening alters the water balance.

Research results are detailed in the reprint *The Effect of Patch Clearcutting on the Water Balance of a Subalpine Forest Slope*. Copies are available from the Rocky Mountain Station.

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